An economic impact of inbreeding in the purebred population of Pinzgau cattle in Slovakia on milk production traits

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ABSTRACT: An increase of inbreeding in a small, endangered population is one of the important criterions in the evaluation of the degree of endangerment of the given breed. The aim was to determine an economic impact of inbreeding in the purebred population of Pinzgau cattle in Slovakia on milk production traits. Pedigree information on 1 611 purebred Pinzgau cows under milk recording was used for the analysis. Average production was 3 898 kg of milk, with 3.93% of fat and 3.31% of proteins. The pedigree of each cow was completed maximally to the 4th generation. Simultaneously, the results from a genetic evaluation of milk production traits such as milk production (M) in kg, fat (F) and protein (P) production in kg and the values of Slovak production index (SPI) of 1 611 cows were collected. Cows were born in 1998–2003. The ratio of inbred cows in the purebred population was 5.7%. Their average Fx = 4.225%. Increased inbreeding has a negative impact on SPI and EBV of milk, fat and protein production. The inbreeding depression was –39.60 SKK in SPI, –8.95 kg in EBV of milk, –0.37 kg in EBV of fat and –0.36 kg in EBV of protein.

Keywords: endangered breed; selection index; breeding value; inbreeding

An increase of inbreeding in a small, endangered population is one of the important criterions in the evaluation of the degree of endangerment of the given breed. The population is endangered if the increase in inbreeding in the population is higher than 1% per generation (Bodó, 1992). A negative impact of inbreeding on production and reproduction traits through an increased risk of inbreeding depression is known from different sources. In Hereford cattle the birth weight decreased by 1.24%. Inbreeding depression per 1% increase of inbreeding was predicted to be up to –30 kg milk, –1.0 kg fat and –1.5 kg body weight (Panicke et al., 1975). This prediction was confirmed by an extensive study based on the individual level within the population, carried out by Cassell et al. (2003a, b) in the USA. The estimated inbreeding depression of milk yield in the first lactation amounted to –27 kg, fat yield and protein yield –0.9 and –0.8 kg. The depression was –177 kg milk, –6 kg fat and –5.5 kg protein per 1% increase in inbreeding. Further, the inbreeding depression in the age of the first calving was +0.55 days, –6 days of productive life and –4.8 milking days. There was no large effect on conformation traits. Sorensen et al. (2004) observed 3.4% average inbreeding for Danish Holstein and 1.3% for Danish Red. Danish Holstein is very close to the minimum effective population size and tools are needed to monitor the selection process in order to control inbreeding and find mating strategies. Kadlečík et al. (2004) evaluated alternatives of breeding program in the Slovak Pinzgau population according to the achieved level of inbreeding. Effective tools dealing with and managing inbreeding in cattle populations providing a given genetic gain at a fixed inbreeding rate by optimizing long-term genetic contributions of ancestors were presented by Bijma and Wooliams (1999) or Weigel and Lin (2000). Long-term selection responses in dairy herds were also compared

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Table 1. Basic statistical parameters of evaluated traits (SBI SR, 2005)

Trait	N	$\overline{x}$	σ_P	Min.	Max.
EBV of milk (kg)	1 611	–89.87	134.10	–606	261.8
EBV of fat (kg)	1 611	–4.51	5.22	–22.99	10.3
EBV of protein (kg)	1 611	–2.69	3.80	–18.46	7.85
SPI (SKK)	1 611	–395.44	505.80	–2 250.00	1 001.0

by Šafus and Přibyl (2005). Software specifically developed for the analysis of large pedigrees to estimate inbreeding coefficients was presented by Boichard et al. (1997). This software, specifically developed for the analysis of large pedigrees (tens of thousands of subjects), is a set of independent programs written in F77, to calculate probabilities of gene origin, relationship and inbreeding coefficient, and to characterize the quality of pedigree information and also pedigree manipulation (Aulchenko et al., 2004).

MATERIAL AND METHODS

Pedigree information on 1 611 purebred living Pinzgau cows under the milk recording of State Breeding Institute was used for the analysis. The pedigree of each cow was completed maximally to the 4^{th} generation. Simultaneously, the results from genetic evaluation of milk production traits such as milk production (M) in kg, fat (F) and protein (P) production in kg and values of Slovak production index (SPI) of 1 611 cows were collected. Cows were born in 1998–2003.

Software package of Boichard et al. (1997) was used to analyze pedigrees of Pinzgau cows. In this package two programs were available to compute inbreeding coefficients of all individuals in a population. The program meuw.f applies the method described by Meuwissen and Luo (1992) and uses the Cholesky factor of the relationship matrix where each row of this factor is built by tracing the entire pedigree of each individual and the inbreeding coefficient is then obtained from the elements of this row and from the inbreeding coefficients of the ancestors. The other program vanrad.f, based on Vanraden (1992), was derived from the tabular method. Its principle consists in building the relationship matrix of each individual and its ancestors. The inbreeding coefficients of all these animals are then deduced from the diagonal elements of this matrix. Both programs provide inbreeding coefficients of inbred individuals similarly in an output file.

Economic importance of inbreeding was evaluated as a statistically significant difference between inbred and outbred cows using Student's t-test. To evaluate an economic impact of inbreeding the cows were divided into 3 groups.

Group 1 consisted of 98 inbred cows with the coefficient of inbreeding (Fx) ≤ 0.01. Group 2 consisted of 90 inbred cows with Fx > 0.01. Group 3 consisted of 1 424 outbred cows. The influence of inbreeding level on EBV of milk, fat and protein production as well as on SPI with the estimation of coefficient of determination (R^2) was realized by regression analysis using a linear model.

Table 2. Distribution of inbreed animals across generations

Generation		N	[1]N_{inb}.	[2]percentage of population	[3]$Fx_{ave.}$
1	♂	–	–	–	–
	♀	1 611	188	11.67	0.02346
2	♂	113	3	0.19	0.01563
	♀	1 494	18	1.11	0.08594
3	♂	246	2	0.12	0.13281
	♀	1 245	–	–	–
4	♂	255	–	–	–
	♀	862	–	–	–

[1]number of inbreed animals; [2]share of ratio in the whole population; [3]average Fx

RESULTS AND DISCUSSION

In the pedigree file there were 5 826 individuals in total. Cows of the first generation (1 611) came from 113 sires and 1 494 dams occurring in pedigrees as the second generation. In the third generation 246 sires and 1 245 dams occurred. The fourth generation was represented by 255 sires and 862 known dams. The parents of animals from the fourth generation were unknown. The parents of the third generation were taken as base animals. In each generation the number of unknown parents increased. Any pedigree information was missing in the second generation. In the third generation the information on 630 parents of mothers was not available. In the fourth generation the information about 34 grandparents of fathers and 2 310 grandparents of mothers was missing.

In the first generation 188 (11.67%) inbred cows were detected. Their frequency according to the level of inbreeding is shown in Figure 1. Average inbreeding of these cows was 0.02346, with minimum $Fx = 0.00049$ (0.5^{11} – the parents have a common ancestor in the fifth generation) and maximum 0.25 (0.5^2 – mating between father and daughter). This result is higher than the value observed in Danish Red by Sorensen et al. (2004), which is also the population close to be endangered. Cows of group 1 had average $Fx = 0.0055$ and cows from group 2 average $Fx = 0.04225$. The second generation had an average level of inbreeding 0.07589 caused by 3 sires, all with the same $Fx = 0.015625$ (0.5^7) and 18 dams with average $Fx = 0.08594$. In the third generation only two inbred cows were detected with $Fx = 0.25$ and 0.015625, respectively. In total 211 inbred animals were detected in pedigrees of purebred cows.

According to the average value of SPI there was a significant difference between two groups of inbred cows, when the cows of group 1 produced by 193.60 SKK SPI more than the cows of group 2 (1 € = 37.60 SKK). A significant difference was also found between the cows of group 1 and the group of outbred cows (group 3) that produced by 26.30 SKK SPI less than group 1. A highly significant difference was found between group 2 and group 3, when group 3 produced by 167.30 SKK SPI more than group 2. The results of regression analysis show a decrease in SPI with increased value of *Fx* between the observed groups. This negative tendency was estimated with $R^2 = 0.66$.

A significant difference was also determined in the estimated breeding value (EBV) of milk production: group 1 produced by 53.50 kg more than group 2. A highly significant difference was found between group 2 and group 3, with the difference of 37.80 kg for group 3. Between group 1 and group 3 there was not a significant difference. The results of regression analysis show a decrease in EBV of milk production with increased value of *Fx* between the observed groups. This negative tendency was estimated with $R^2 = 0.50$.

A highly significant difference of 2 kg was found in EBV of fat production for group 1 over group 2 and 1.55 kg for group 3 over group 2. The difference between group 1 and group 3 was not significant. The results of regression analysis show a decrease in EBV of fat production with increased value of *Fx* between the observed groups. This negative tendency was estimated with $R^2 = 0.40$.

Similarly, in EBV of protein production differences with high significance were found for group 1 over group 2 of 1.46 kg and group 3 over group 2 of 1.53 kg. The difference between group 1 and group 3

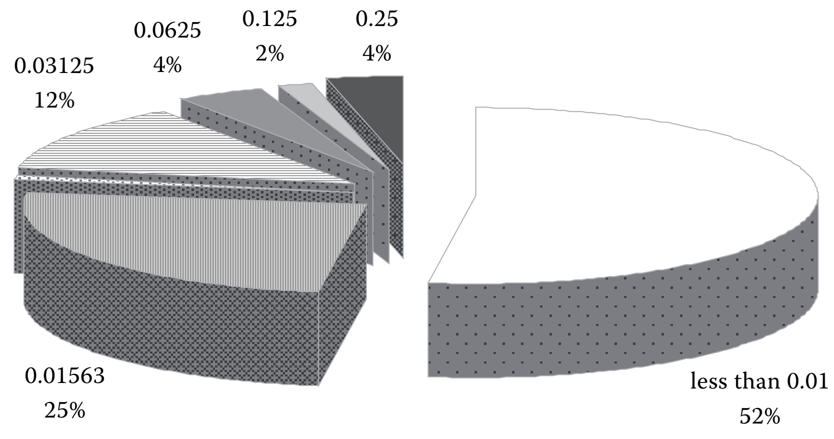

Figure 1. Frequency of inbred Pinzgau cows of the first generation according to the coefficient of inbreeding

Table 3. Observed differences of selected traits between 3 groups of animals according to *Fx*

Group A	Group B	SPI (SKK)	EBV (kg)		
			milk	fat	protein
1	2	193.60*	53.50*	2.00**	1.46**
1	3	26.30*	–	–	–
2	3	–167.30**	–37.80**	–1.55**	–1.53**

*$P \leq 0.05$; **$P \leq 0.01$; $^{-}P > 0.05$; 1 € = 37.60 SKK

was not significant. Group 1 could be treated as outbred. The results of regression analysis show a clear decrease in EBV of milk production with increased value of *Fx* between the observed groups. This negative tendency was estimated with $R^2 = 0.84$.

Inbreeding depression per 1% of inbreeding is –39.60 SKK of SPI, –8.95 kg in EBV of milk, –0.37 kg in EBV of fat and –0.36 kg in EBV of protein. The results are comparable with findings of Panicke et al. (1975), Smith et al. (1998) and Cassel et al. (2003a,b) achieved in populations of dairy cattle.

CONCLUSIONS

Differences between group 1 and group 3 showed no significant difference in EBV's, a difference was found only in SPI. This can possibly lead to conclusions that the coefficient of inbreeding lower than 0.01 in pedigrees of animals does not affect milk production EBV's and SPI and those animals can be treated as outbred. Consequently, the ratio of inbred cows in the purebred population decreases to the value of 5.7%. Their average value of the coefficient of inbreeding is 4.225%. Increased inbreeding has a negative impact on SPI and EBV of milk, fat and protein production. Based on the results inbreeding depression –39.60 SKK of SPI, 8.95 kg in EBV of milk, 0.37 kg in EBV of fat and 0.36 kg in EBV of protein was observed. The fact that inbreeding causes depression of milk production traits and SPI must lead to proper look out in selection of cattle. Further study on the relevance of inbreeding for other production, reproduction and functional traits is needed.

REFERENCES

Aulchenko Y. et al. (2004): RN List. Version 2.0, 54 pp.

Bijma P., Wooliams J.A. (1999): Prediction of genetic contributions and generation intervals in populations with overlapping generations under selection. Genetics, 151, 1197–1210.

Bodó I. (1992): Monitoring Animal Genetic Resources and criteria for priority order of endangered breeds. In: The Management of Global Animal Genetic Resources. Proc. FAO Expert Consultation, Rome, Italy. 91–107.

Boichard D., Maignel L., Verrier E. (1997): The value of using probabilities of gene origin to measure genetic variability in a population. Genet. Sel. Evol., *29*, 5–23.

Cassell B.G., Adamec V., Pearson R.E. (2003a): Effect of incomplete pedigrees on estimates of inbreeding and inbreeding depression for days to first service and summit milk yield in Holsteins and Jerseys. J. Dairy Sci., 86, 2967–2976.

Cassell B.G., Adamec V., Pearson R.E. (2003b): Paternal and maternal inbreeding depression for 70-day nonreturn and calving rate in Holsteins and Jerseys. J. Dairy Sci., 86, 2977–2983.

Kadlečík O., Kasarda R., Hetényi L. (2004): Genetic gain, increase of inbreeding rate and generation interval in alternatives of Pinzgau breeding program. Czech J. Anim. Sci., 49, 524–531.

Meuwissen T.H.E., Luo Z. (1992): Computing inbreeding coefficient in large populations. Genet. Sel. Evol., 24, 305–313.

Panicke L., Rybka P., Engel S., Schüler E., Anacker G., Lembke K. (1975): Studie – Möglichkeit für die planmäßige Nutzung von Heterosis und Inzucht in der Milchrindzüchtung. Forschungszentrum für Tierproduktion, Dummerstorf.

SBI SR (2005): Results of cows' milk recording in Slovakia (control year 2004–2005). The State Breeding Institute of the Slovak Republic, Bratislava.

Smith G.E., Cassell B.G., Pearson R.E. (1998): The effect of inbreeding on the lifetime performance of dairy cattle. J. Dairy Sci., 81, 2729–2737.

Sorensen C.A., Sorensen M.K., Berg P. (2004): Inbreeding in Danish dairy cattle populations. EAAP – 55th Annual Meeting, Bled Book of Abstracts, 30 pp.

Šafus P., Přibyl J. (2005): Comparison of long-term selection responses of breeding policy in dairy herds. Czech J. Anim. Sci, 50, 439–449.

Vanraden P.M. (1992): Accounting for inbreeding and crossbreeding in genetic evaluation for large populations. J. Dairy Sci., 75, 3136–3144.

Weigel K.A., Lin S.W. (2000): Use of computerized mate selection programs to control inbreeding of Holstein and Jersey cattle in the next generation. J. Dairy Sci., 83, 822–828.

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